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14. ABSTRACT

The objectives of this research program were: 1) to examine the sediment transport mechanisms on the Po delta, particularly the role of fluid mud flows on sediment dispersal; 2) to quantify the dynamics of the western Adriatic coastal current and its role in along-shelf and cross-shelf sediment transport; 3) to make rigorous comparisons between observations and models of the transport processes on the Po delta and the coastal current in order to improve the predictions of sediment transport and morphodynamic evolution.

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Final Report: EuroStrataform Analysis

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LONG-TERM GOALS

The long-term goal of this project was to develop quantitative models of sediment transport, resuspension, deposition and accumulation on the continental margin.

OBJECTIVES

The objectives of this research program were: 1) to examine the sediment transport mechanisms on the Po delta, particularly the role of fluid mud flows on sediment dispersal; 2) to quantify the dynamics of the western Adriatic coastal current and its role in along-shelf and cross-shelf sediment transport; 3) to make rigorous comparisons between observations and models of the transport processes on the Po delta and the coastal current in order to improve the predictions of sediment transport and morphodynamic evolution.

APPROACH

This research effort included data analysis and model-data comparison. The data were collected during the field portion of the Po and Apennine Sediment Transport and Accumulation (PASTA) study, principally from the period from October, 2002 to June, 2003. The data include moorings and tripods deployed along the western margin of the Adriatic, from the mouth of the Po River to Pescara, including instruments deployed by Woods Hole Oceanographic Institution, University of Washington, Institut de Ciències del Mar (Barcelona) and the U.S. Geological Survey. The data analysis also involved hydrographic data collected during several cruises over the same interval. Additional timeseries and shipboard data from the Adriatic Circulation Experiment in the northern Adriatic Sea were also used for characterization of the far-field conditions.

The data analysis addressed two main themes: 1) the processes affecting the suspended sediment distribution and dispersal in the vicinity of the Po delta, and 2) the dynamics and sediment transport associated with the western Adriatic coastal current. Traykovski was principally engaged in the investigations of the Po delta. He focused on the detailed analysis of the near-bed suspended sediment distribution, including wave-induced sediment resuspension and fluid-mud flows. Geyer (in collaboration mainly with Kineke, Mullenbach, Sherwood and Harris) examined the dynamics of the coastal current and its associated sediment transport processes.

The model-data comparison involved detailed comparisons of model results with moored and shipboard observations. The initial comparisons are used to refine the model parameterizations and input functions (e.g., bottom boundary conditions for sediment resuspension. The model also provides a framework for kinematic and dynamical analysis, for example to assess the relative roles of pressure gradients and wind stress in driving the along-shelf motions.

RESULTS

Po Delta Processes

Traykovski et al. (2006) demonstrate that fluid-mud flows provide an important source of off-shelf sediment transport on the Po prodelta. The magnitude of sediment flux at the Tolle distributary, where the tripods were located, was actually greater in the along-shelf direction (driven by the Bora winds). However, model calculations indicate that at the Pila mouth, the larger sediment fluxes and steeper foreset beds may produce cross-shelf, gravity-driven transport that represents a more significant fraction of the total sediment flux from the Po, than could be accounted for by cross-shelf transport at the Tolle distributary.

Traykovski et al. (2006) also use the one-dimensional model of the gravity-driven flows to compare the processes on the Po delta to the Eel shelf. The model correctly predicts the magnitudes of sediment fluxes in the two environments and the sharply contrasting depths of sediment transport in the two sites. Although the down slope gravitation forces at the two sites differ by an order of magnitude due to the higher concentrations and thicker flows at the Eel, the dynamic balance at both sites are essentially the same and are well described by a Chezy balance with a single drag coefficient for both sites. The much longer and larger waves on the Eel shelf result in gravity flows extending past 60-m water depth, whereas in the Adriatic, the gravity-driven transport extends only to 25-m (Figures 1 and 2).

Western Adriatic Coastal Current Dynamics

Geyer's analysis of the coastal current demonstrates that the wind field has fundamental importance in determining the transport within the coastal current. The freshwater transport at Chienti (Fig. 3) provides an integral representation of the strength of the coastal current. The analysis distinguished the transport due to buoyancy (the density difference between fresh and salt-water) and wind-forcing. Roughly half the transport could be accounted for by buoyancy effects, and the rest is due to the winds. The winds also control the vertical structure of the coastal current. The combination of vertical mixing and downwelling during Bora events results in rapid homogenization density structure of the water column. This process actually reduces the offshore transport due to downwelling, and causes the coastal current to be more retentive in the cross-shelf direction. This helps explain the extreme distances of along-shelf transport of fresh water and sediment accomplished by the Western Adriatic coastal Current.

Sediment Transport in the Coastal Current

Sediment transport within the coastal current was undertaken as a collaboration with Beth Mullenbach (Texas A&M) and Chris Sherwood (USGS). The sediment flux was quantified within the coastal current based on acoustic backscatter measurements at the Chienti site. One of the key findings is the role of the wind-stress forcing in the delivery of sediment. The dominant fraction of sediment flux occurs during the Bora wind forcing events, which result both in high suspended sediment concentrations and strong southward currents (fig. 4). This finding has general application to coastal current dispersal systems. Another important result was the determination of an approximate mass of sediment transported in the coastal current. Although there was some uncertainty of the calibration of the acoustic sensors, a conservative estimate of the sediment flux during the 2002-2003 deployment period is more than 4 million tons (Fig. 4). This indicates that the coastal current is still an active conduit of sediment, even though the sediment supply from the Po and the Apennine rivers has significantly diminished in recent years. This estimate helps link together the observations of fluvial processes, near-shore sediment transport, and sediment deposition patterns. The conclusion is that the system is still actively redistributing sediment along the margin, and still delivering sediment to the clinoform, although at a diminished rate from its average over the last few millennia.

Model-Data Comparison and Analysis

Data-model comparison has been crucial for the specification of the boundary condition for sediment resuspension. The combination of in situ erosion experiments and observations of suspended sediment concentrations has been essential in specifying the sediment erosion threshold for the model as well as the supply of erodible sediment. Guided by these experiments and observations, the model is providing a realistic representation of the sediment transport processes in the coastal current. The remaining challenge is to obtain quantitative simulations of net sediment deposition and erosion.

IMPACT/APPLICATIONS

The research is providing fundamental new insights about the dynamics and morphodynamics of river deltas and coastal current regimes. The identification of fluid-mud flows in a river delta region is of particular importance for mine countermeasures, navigation and acoustics. The coastal current dynamics and sediment transport processes have implications on larger spatial scales for the same naval issues. The work has lead to significant improvement of coastal circulation models for the prediction of water clarity and seabed characterization.

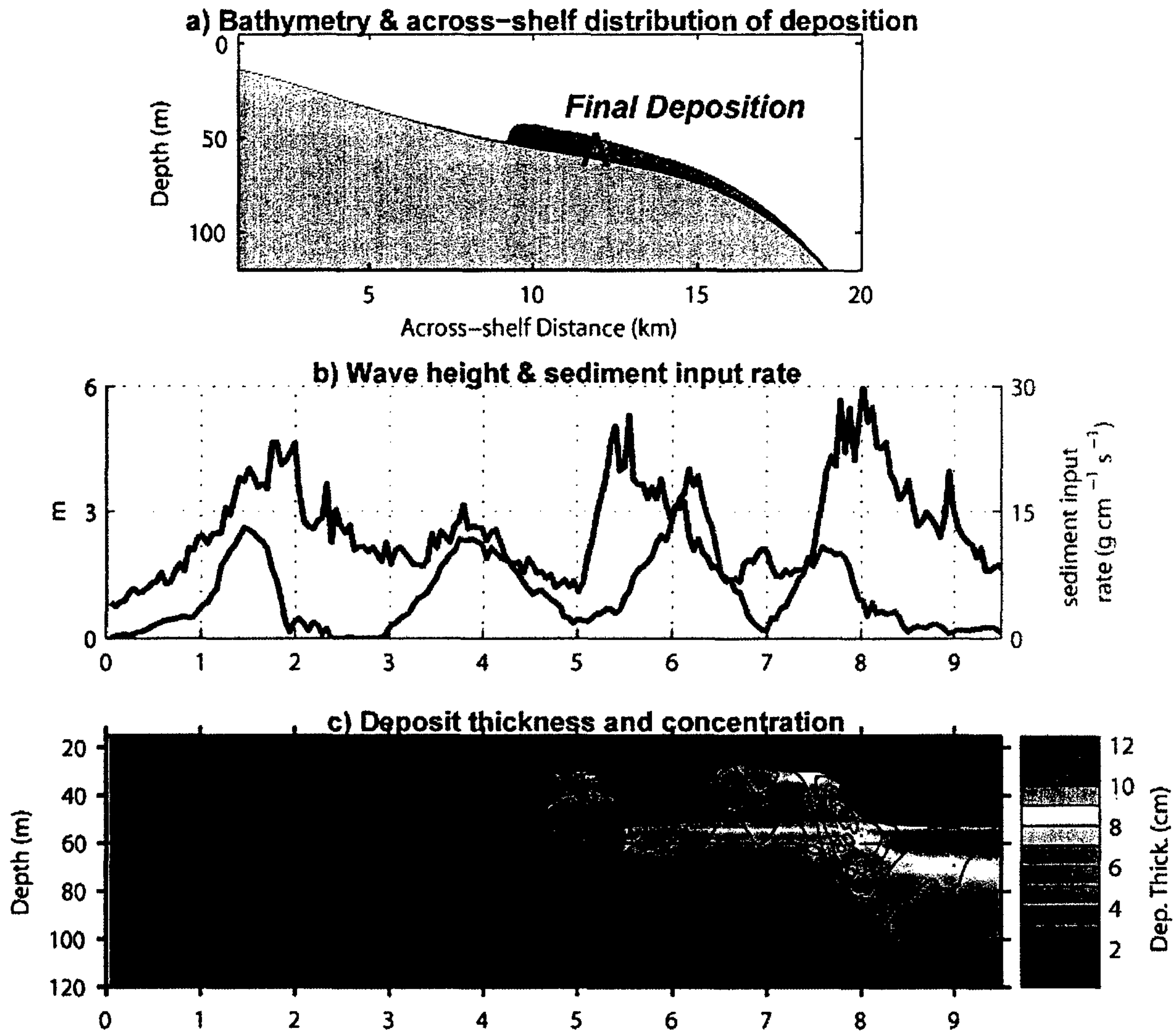

Figure 1. Model Runs for the Eel Shelf. a) Bathymetry, initial and final distribution of sediment deposition thickness. The vertical scale for the sediment deposition has been exaggerated by a factor of 100. The location of the tripod is indicated by A. b) Wave height (left y-axis) and sediment input rate (right y-axis, proportional to river discharge). c) Temporal and depth dependence of deposition (color scale) and suspended sediment concentration within the wave boundary layer (contours with units of g/l). A dashed line at 60 m depth depicts the tripod location. Due to the large waves and long wave period at the Eel site wave-supported turbidity currents were able to transport sediment to the 50 to 90 m isobath where it was deposited

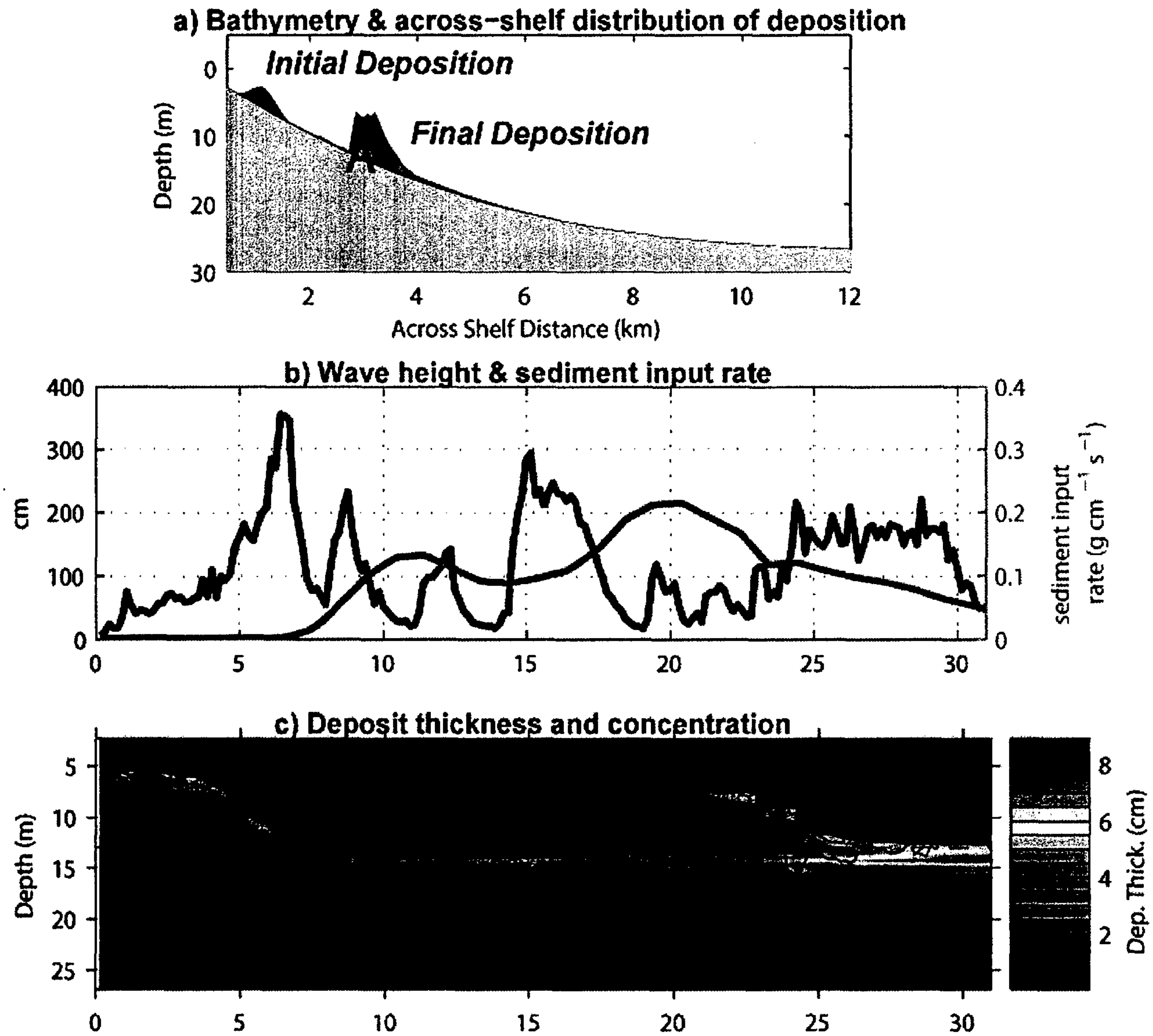

Figure 2. Model Runs for the Po prodelta. a) Bathymetry, initial and final distribution of sediment deposition thickness. The vertical scale for the sediment deposition has been exaggerated by a factor of 100. The location of the tripod is indicated by A. b) Wave height (left y-axis) and sediment input rate (right y-axis, proportional to river discharge). c) Temporal and depth dependence of deposition (color scale) and suspended sediment concentration within the wave boundary layer (contours with units of g/l). A dashed line at 13 m depth depicts the tripod location. Due to the slightly smaller waves compared to the Eel and significantly shorter wave period at the Po site wave-supported turbidity currents were able to transport sediment to the 13 to15 m isobath where it was deposited

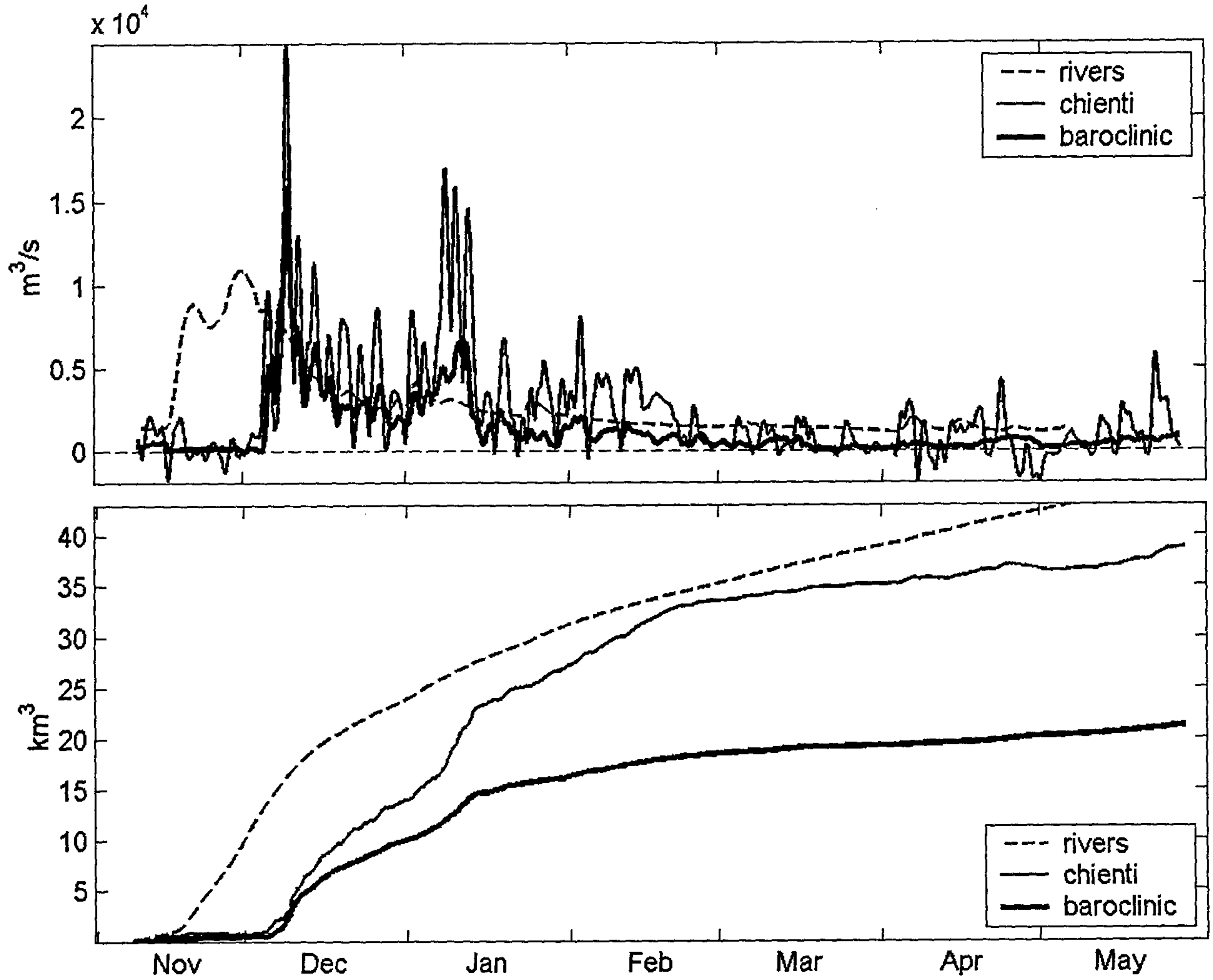

Figure 3. Freshwater transport of the Po River and other northern Adriatic Rivers compared to calculated transport at Chienti (top panel), and integrated freshwater volume (lower panel). The "baroclinic" component is the part of the transport that is explained by the density contrast between fresh and salt water. The large peaks in freshwater transport are due to Bora wind events. The integrated transport shows that the freshwater volume of the coastal current is approximately the same as that of the river outflow; (the difference is due to freshwater remaining in the northern Adriatic).

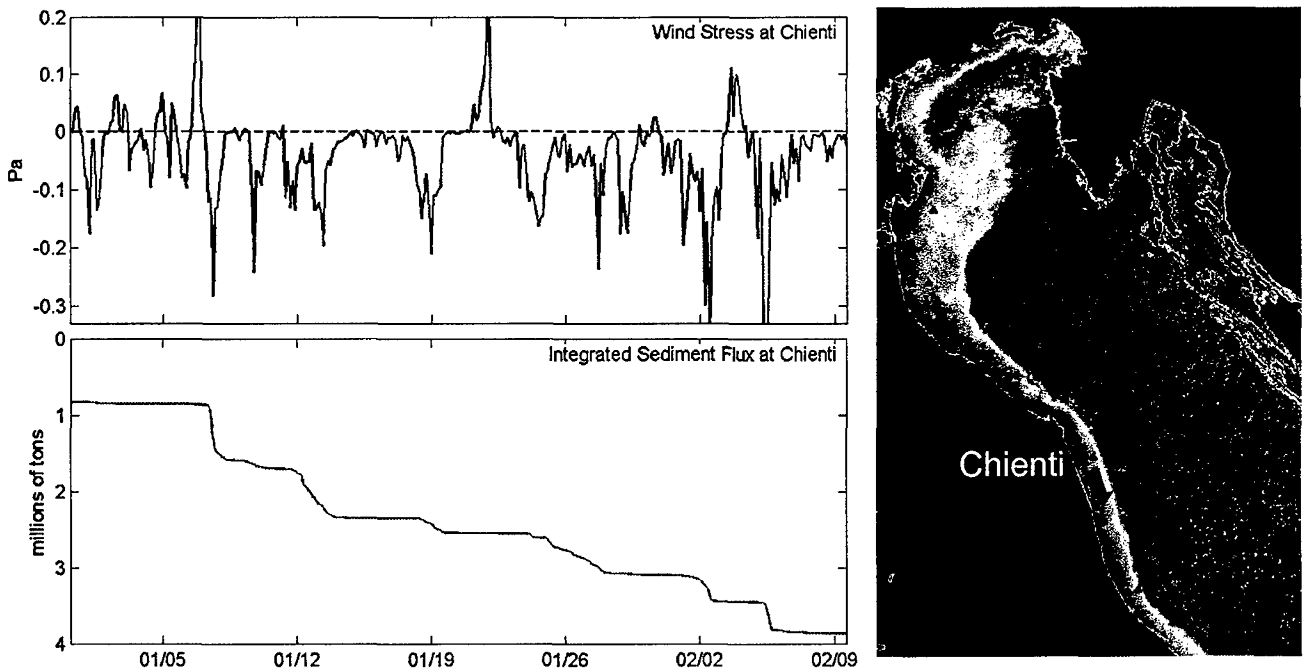

Figure 4. Wind stress and integrated sediment flux at Chienti (left panels) and MODIS satellite image of the Adriatic (average of clear images for month of January, 2003. The estimates of sediment flux were based on acoustic backscatter data from the tripods at positions indicatedon the satellite image. The large sediment fluxes occurred during strong southward (Bora) wind events.

PUBLICATIONS

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